new techniques for the kSZ

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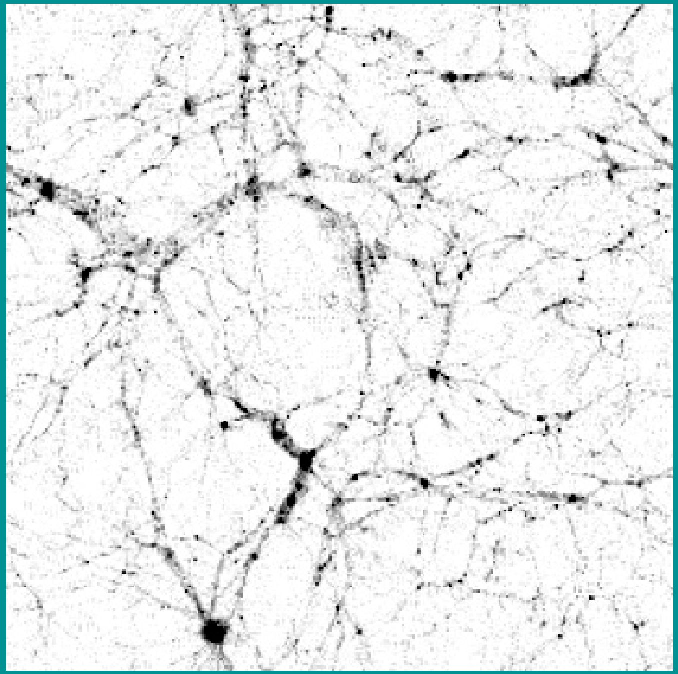
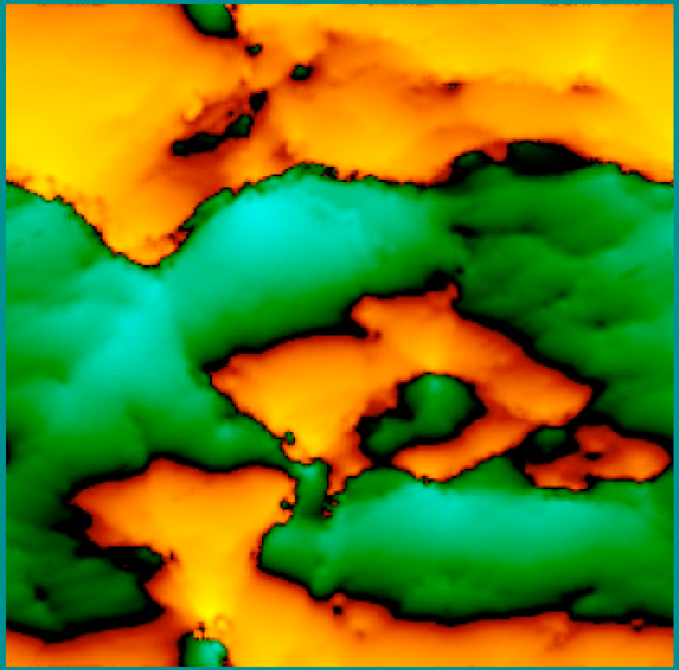


x



$$\mathbf{v}(\mathbf{k},a) \propto H(a)\frac{d\ln D}{d\ln a}\delta(k)\frac{\mathbf{k}}{k^2}$$

collaborators

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physics of the kSZ

the "first order" brother to the tSZ:

tSZ: hot gas, random motion:

$$\langle v \rangle = 0; \langle v^2 \rangle \neq 0$$

second order term in relativistic doppler shift;
non-thermal spectrum, parametrize with "*y*"

traces pressure

kSZ: non-relativistic bulk flows; thermal spectrum
(though second-order corrections *may* be required)

traces momentum

issues for the CMB experiments

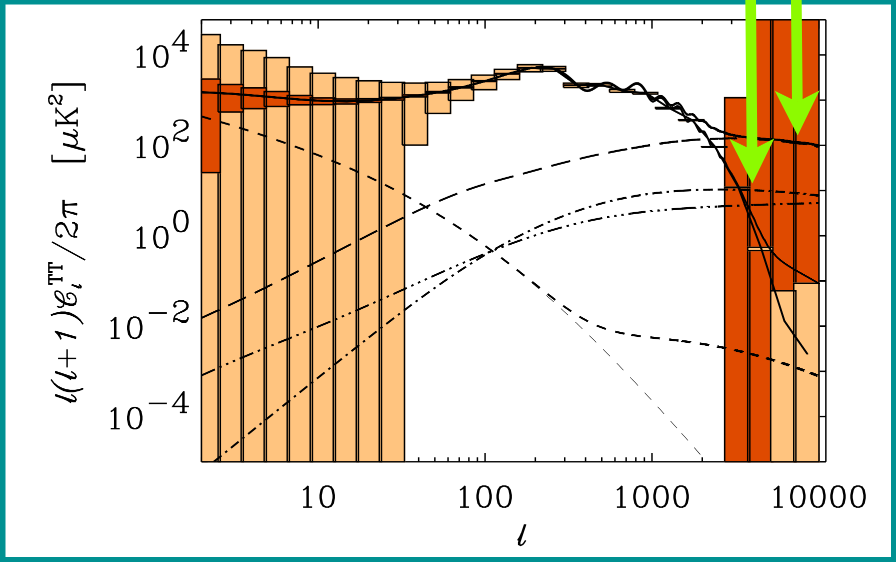
1. detecting it at all — a very small signal

2. “cleaning” off the tSZ — a much stronger signal

3. resolution to push past the “damping tail”

ACT? SPT? — both can in principle detect it.

(4. patchy reionization?)

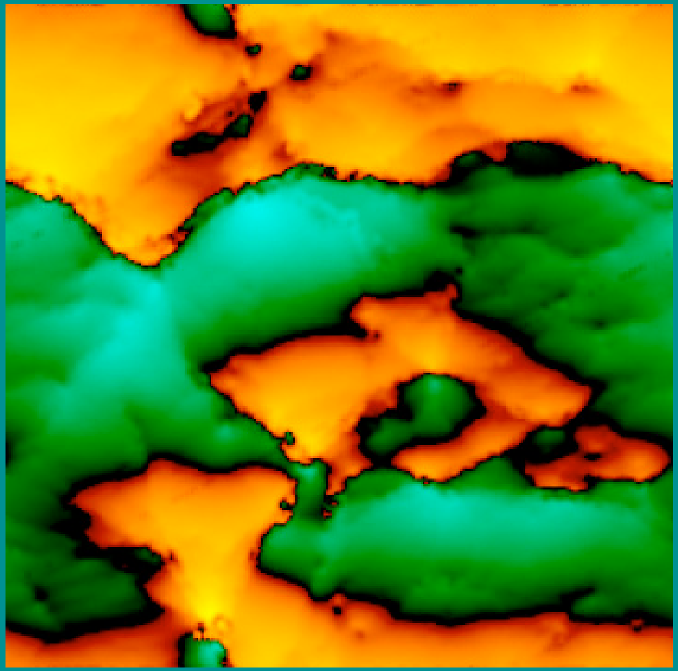


two ways of looking at the kSZ

1. the "classical" version (Ostriker & Vishniac, 1987)
    - extract from a survey in Fourier space
2. the "modern" fashion (e.g., Jimenez, 2005)
    - "circle clusters, look behind"

the classical version (I)

problem: in the linear regime, velocity flows are linear



line of sight (up the screen) velocity green, towards; orange, away

flows are *gradient*;
v and **k** are aligned:

$$\mathbf{v}(\mathbf{k}, a) \propto H(a) \frac{d \ln D}{d \ln a} \delta(k) \frac{\mathbf{k}}{k^2}$$

in the Limber approximation, should be no signal!
(Kaiser, 1984)

the classical version (2)

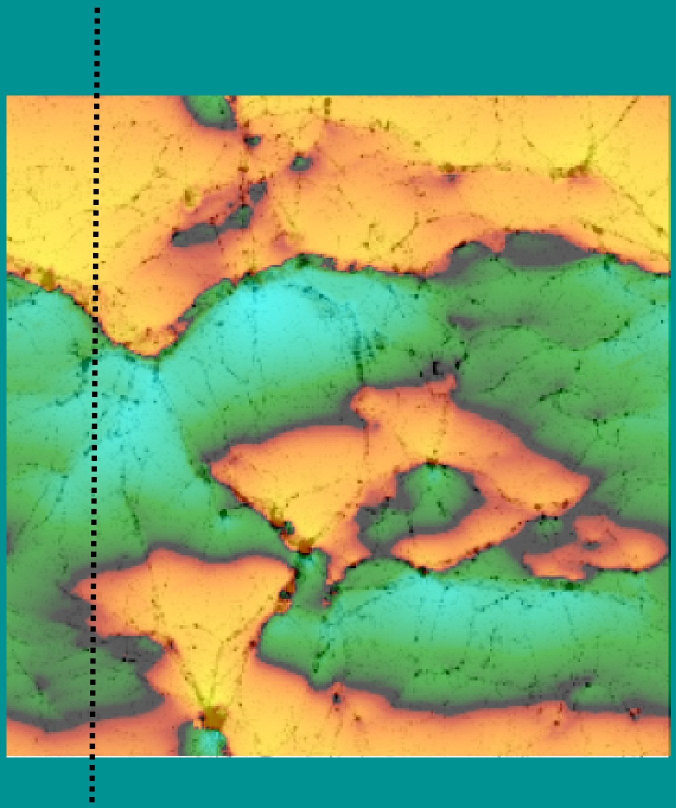
insight (Ostriker & Vishniac, 1987):

kSZ traces the *momentum*; so look to the non-linear:

$$T_{\mathrm{kSZ}} \propto (1 + \underline{\delta)v}$$

pure gradient

"curl" component emerges

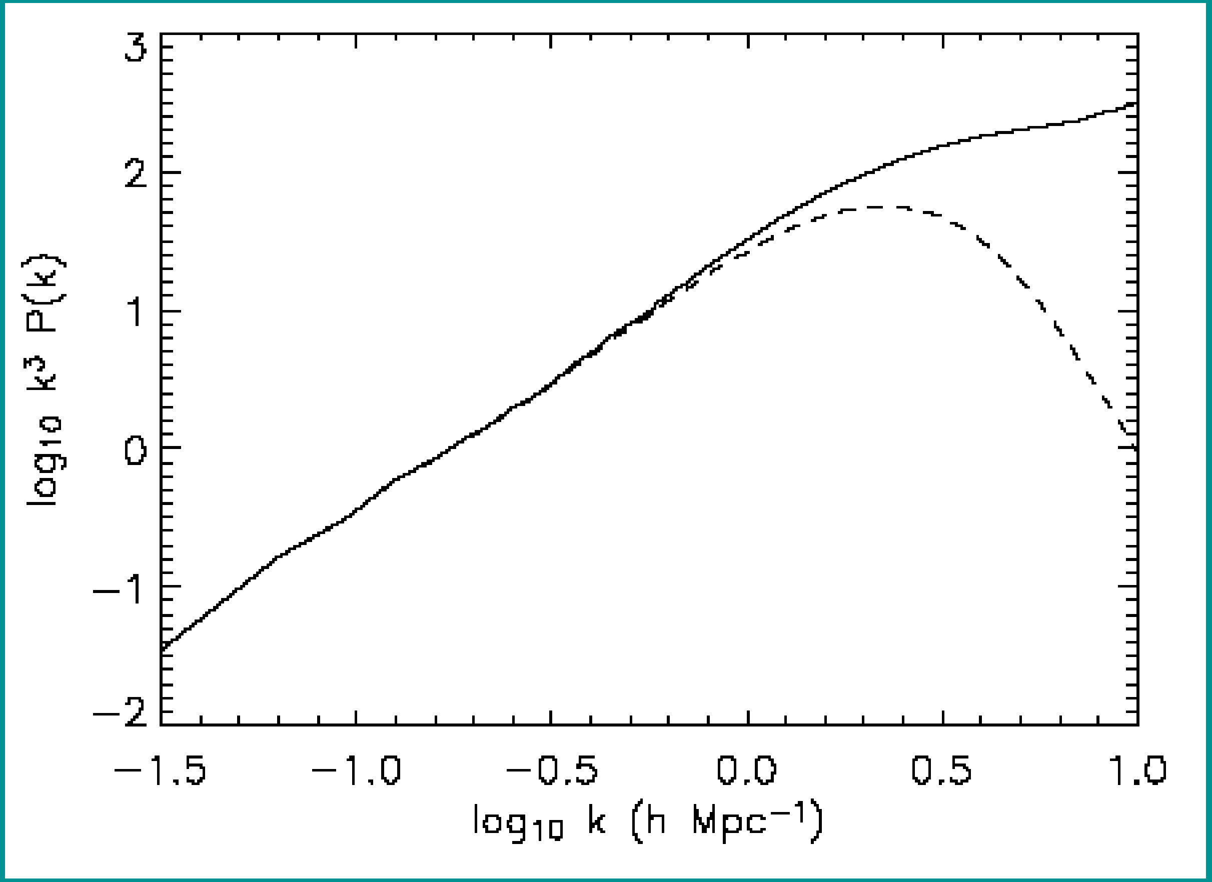


velocity averages out, but not momentum; projected power of momentum "curl" gives CMB fluctuations

important “global” questions

- how does ionization fraction evolve over time? (feeds into cosmological parameters)
- how does gas trace matter?

(effective, redshift-independent smoothing length is a good [1-5%] guess.) — approx 400 kpc scale.



three ways to detect the kSZ in cross-correlation with density field

1. correlate the a_{lm}s
DeDeo, Trac & Spergel (2005)

2. circle the clusters
Jimenez et al. (2005)

3. reconstruct the velocity field
DeDeo & al. (2006, in prep)

1. correlate the a_{lm}s

DeDeo, Trac & Spergel (2005)

Slightly tricky: galaxies can be moving towards or away.

Hence: must correlate velocity squared: $\langle T^2 \delta_g \rangle$

$$\langle T^2 \delta_g \rangle = (\mathrm{bias}) \langle v v \delta_m \delta_m \delta_m \rangle \approx v_{\mathrm{rms}}^2 \langle \delta_m \delta_m \delta_m \rangle$$

Need to know the matter *bispectrum* to determine cosmological parameters.

Do simple "tomography": $\Delta z \approx$ *0.1*

2. “circle the clusters”

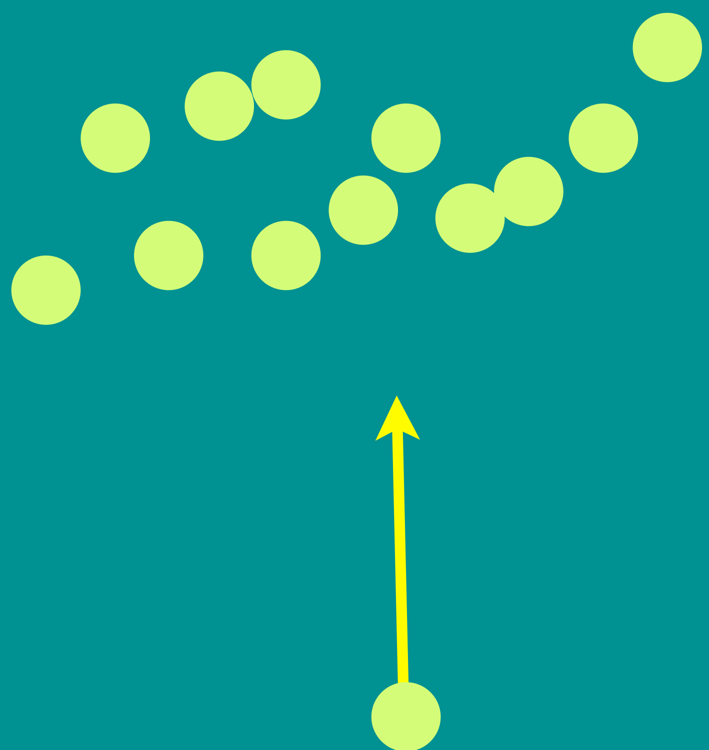
Look for velocity correlation function

Jiminez et al., many others

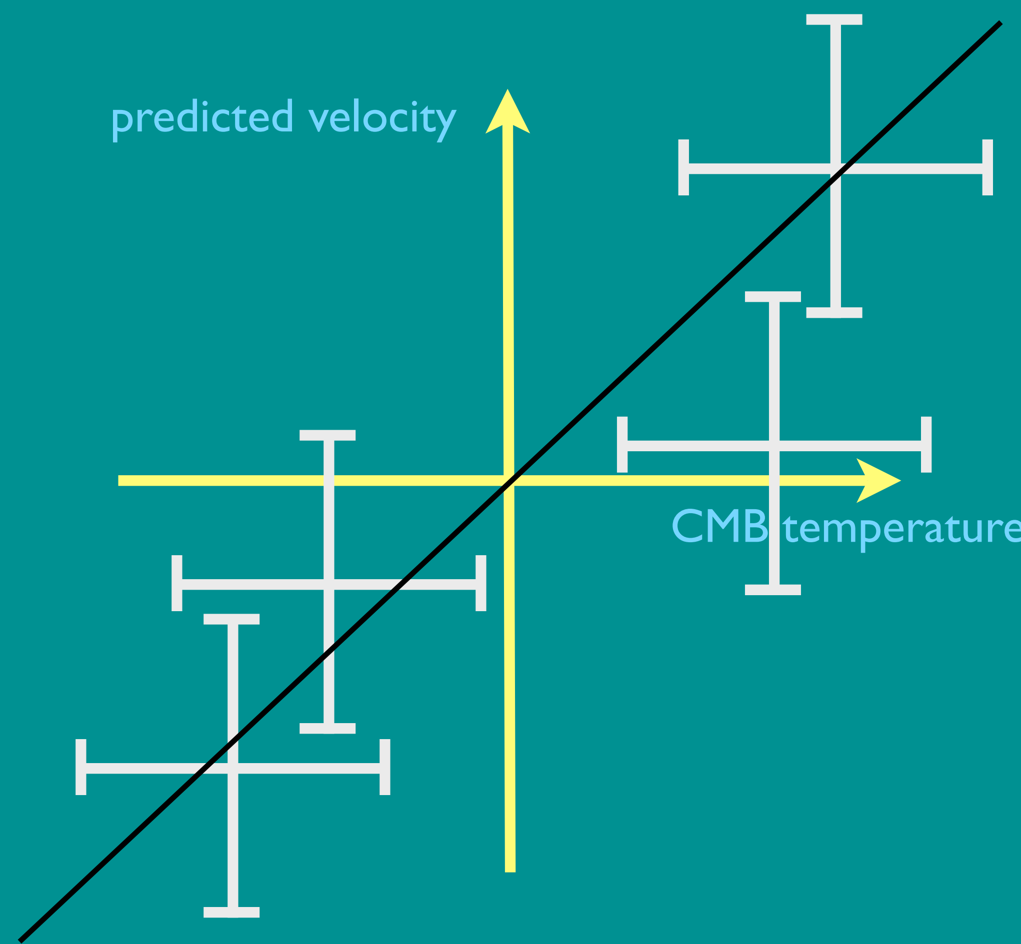
(note: cannot just stack as in the tSZ because velocities will average down)

3. reconstruct the velocity field
DeDeo & Spergel (2006, in prep)

Ambitious — exciting: why not use the density field on large scales to *reconstruct* the velocity field?



need $\Delta z \approx 0.01$



3. reconstruct the velocity field
DeDeo & Spergel (2006, in prep)

Advantages: *more information*. Get a handle on the phase of the velocity, as well as a direct (intuitive) study of both the evolution of gas, and the acceleration of flows.

- how well can we determine the velocity field?

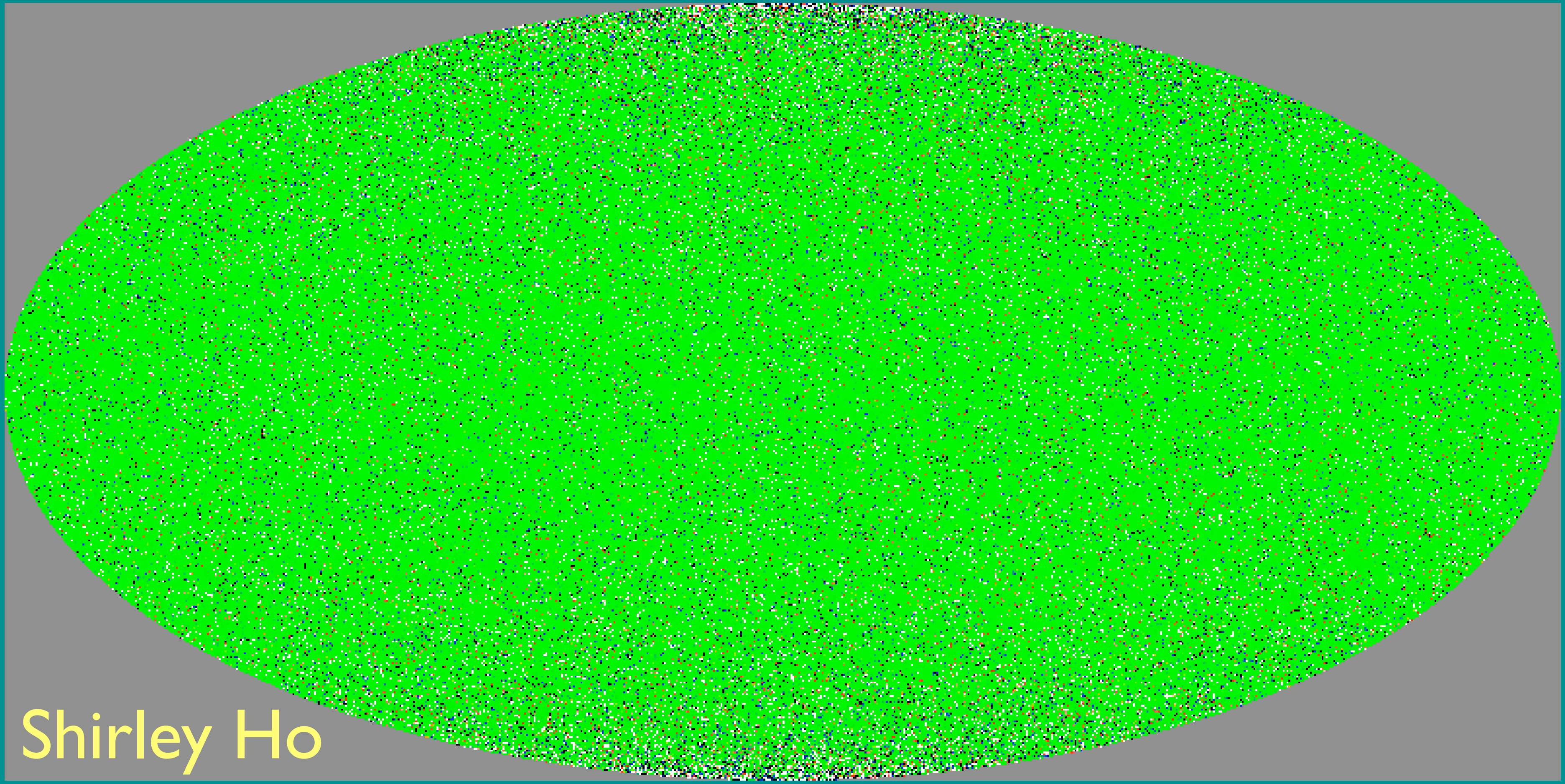
  ⇒ Poisson noise

  ⇒ avoid small-scale non-linearity

- how well can we filter and model?

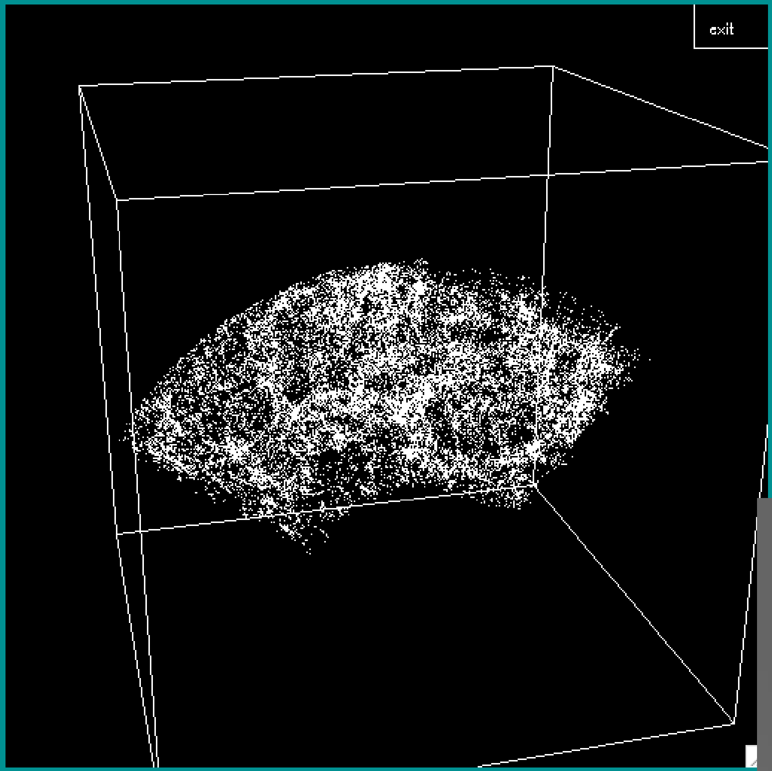
reconstruction (1)

• could just use the Tully-Fisher relation to subtract off the Hubble flow — use this to make a template to tell you where to look in WMAP



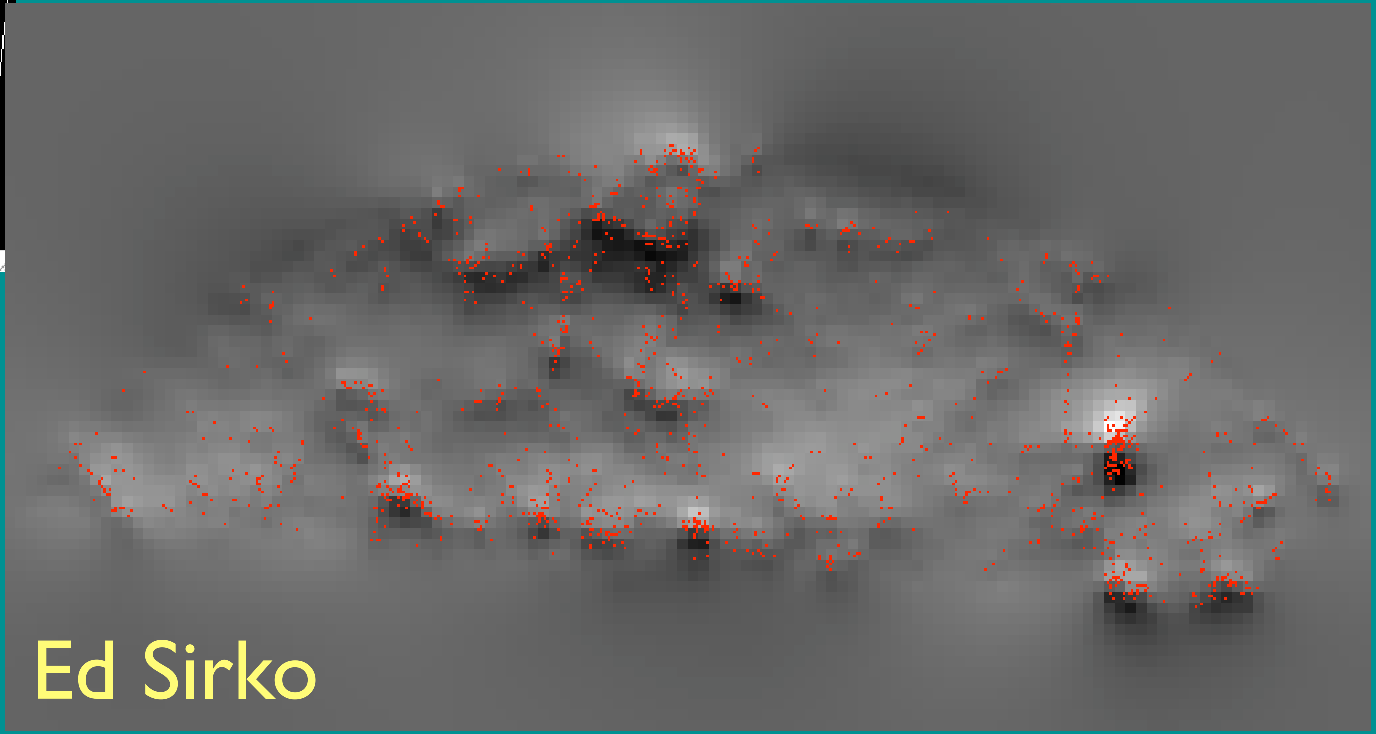
reconstruction (II)

- use the linear density-velocity relationship — take the density, pad, and transform



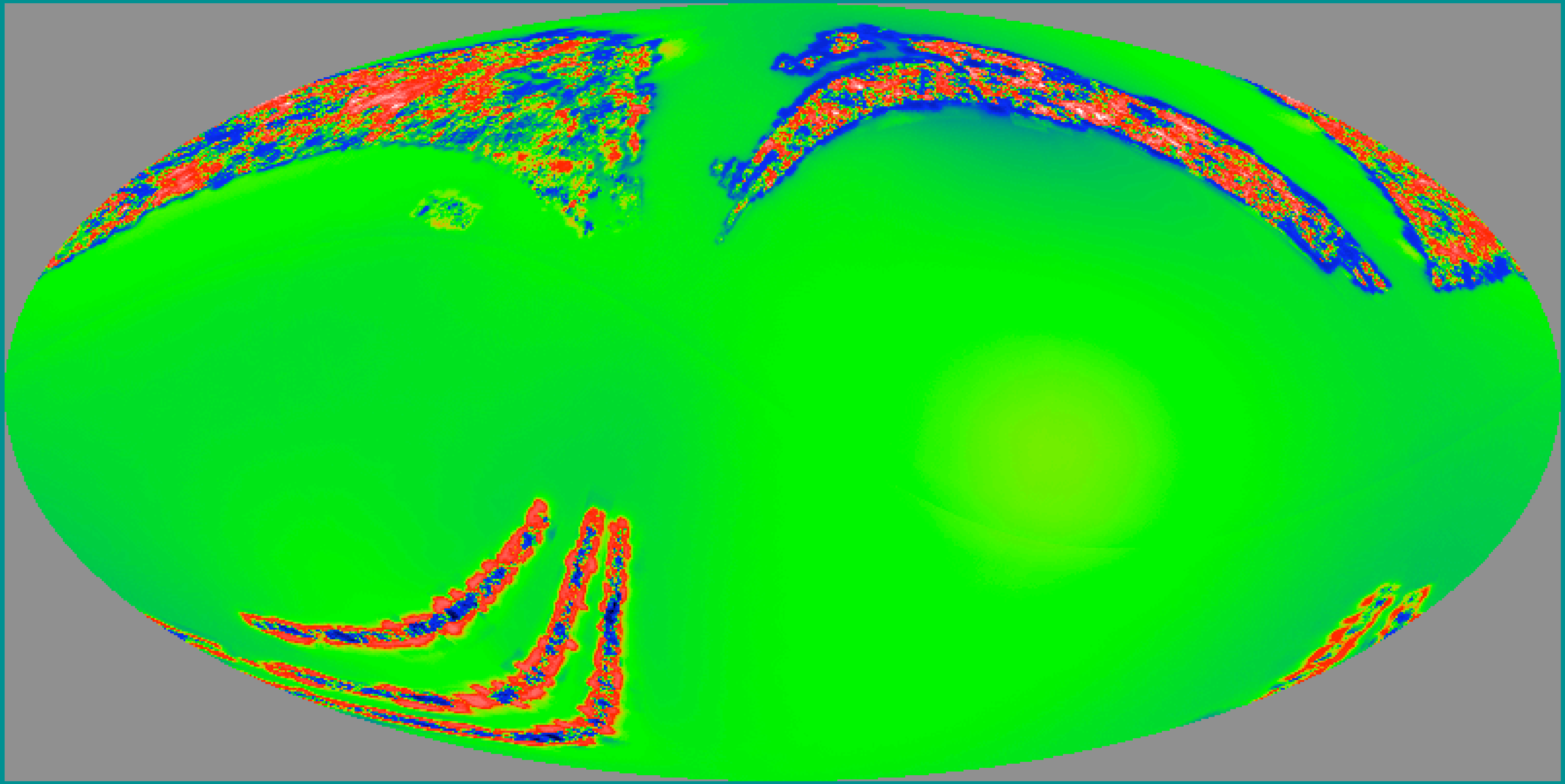
$$\mathbf{v}(\mathbf{k}, a) \propto H(a) \frac{d \ln D}{d \ln a} \delta(k) \frac{\mathbf{k}}{k^2}$$

SDSS volume-limited reconstruction



reconstruction (III)

• full reconstruction of the kSZ signal with DR4 (DR5 coming) spectroscopic sample: cross-correlate this with WMAP3



DR4 kSZ template

"Simple" thoughts:

1. the kSZ is out there, detectable: may even be detectable in SDSS/WMAP.

2. will definitely be detectable to high SN (>100) in an ACT/DES survey.

3. the information is rich enough to constrain both physics and cosmology.

4. the "technology" is in place, and being improved.